High-resolution ice nucleation spectra of sea-ice bacteria: Implications for cloud formation and life in frozen environments

Brian Swanson
Dept. of Earth and Space Sciences
University of Washington

Karen Junge
Applied Physics Laboratory
University of Washington
Introduction

• Objectives
  » To better understand the interaction of bacteria with ice
  » To assess the ice initiation potential of polar marine psychrophiles

• Significance
  » limits of life  
    ‣ active sea-ice bacteria to -20°C (and below Junge et al., 2004 & 2006)
  » sea-ice ecosystem  
    ‣ initial freezing events (Parker et al., 1985)
  » cloud formation  
    ‣ source of ice forming particles in Arctic clouds (Bigg and Leck, 2001)
      After all, many bacteria are CCN active (Bauer et al. 2003)
  » astrobiology

• Fundamental question:

  Do psychrophiles express ice nucleation activity as a means to enhance survival in subzero environments -- whether in sea ice or in the upper atmosphere?
Sea-ice bacterial isolates:

- Arctic: Chukchi Sea
- Antarctica: McMurdo Sound

Bacteria attached to ice wall (Junge et al. 2001)

**Fig. 2.** Phylogenetic analysis of Arctic sea-ice bacteria and closest relatives as determined by Blast Genbank search (Junge et al., 2000). Bacteria strains used for INA tests marked red.
Freezing Tube Apparatus

- High repetition rates (~5 hz)
- Well controlled solution concentration
- Telemicroscopic droplet images
- No substrate-induced nucleation or contamination

D/T = Depolarized scattering intensity/Total scattering intensity

From D/T at various heights we extract the fraction of frozen droplets F(T)
Ice nucleation spectra for sea-ice bacteria isolates

Artificial seawater

Pseudomonas syringae

Sea-ice bacteria

dist. water

Each data point represents F(T) for 200-300 droplets

Calibrations were done to insure at least 1 bacteria per droplet

(Junge et al. in prep.)
Summary

• We have used a novel freeze tube method to study biogenic ice nucleation.
• We find substrate-free methods are useful. Anomalously high ice nucleation temperatures can be obtained if a substrate is not sufficiently passivated for low-temperature nucleation studies.
• Results from 17 different sea-ice bacteria and virus isolates show limited ice nucleation activity
  • Ice initiation mediated by bacteria and virus isolates was at or near homogeneous nucleation temperature (\(-37^\circ C \text{ to } -44^\circ C\))
• Results indicate that avoidance of ice formation in close proximity of their cells may be one of the cold-adaption and survival strategies for sea-ice bacteria and could be important for their ability to remain active at temperatures far below the freezing point of seawater.